SQL:
Indexes and performance

2 TIN
Databases II

INDEXES and PERFORMANCE

Is performance still relevant?

Because:

Transistor density on a manufactured semiconductor doubles about every 18 months.

Moore's law

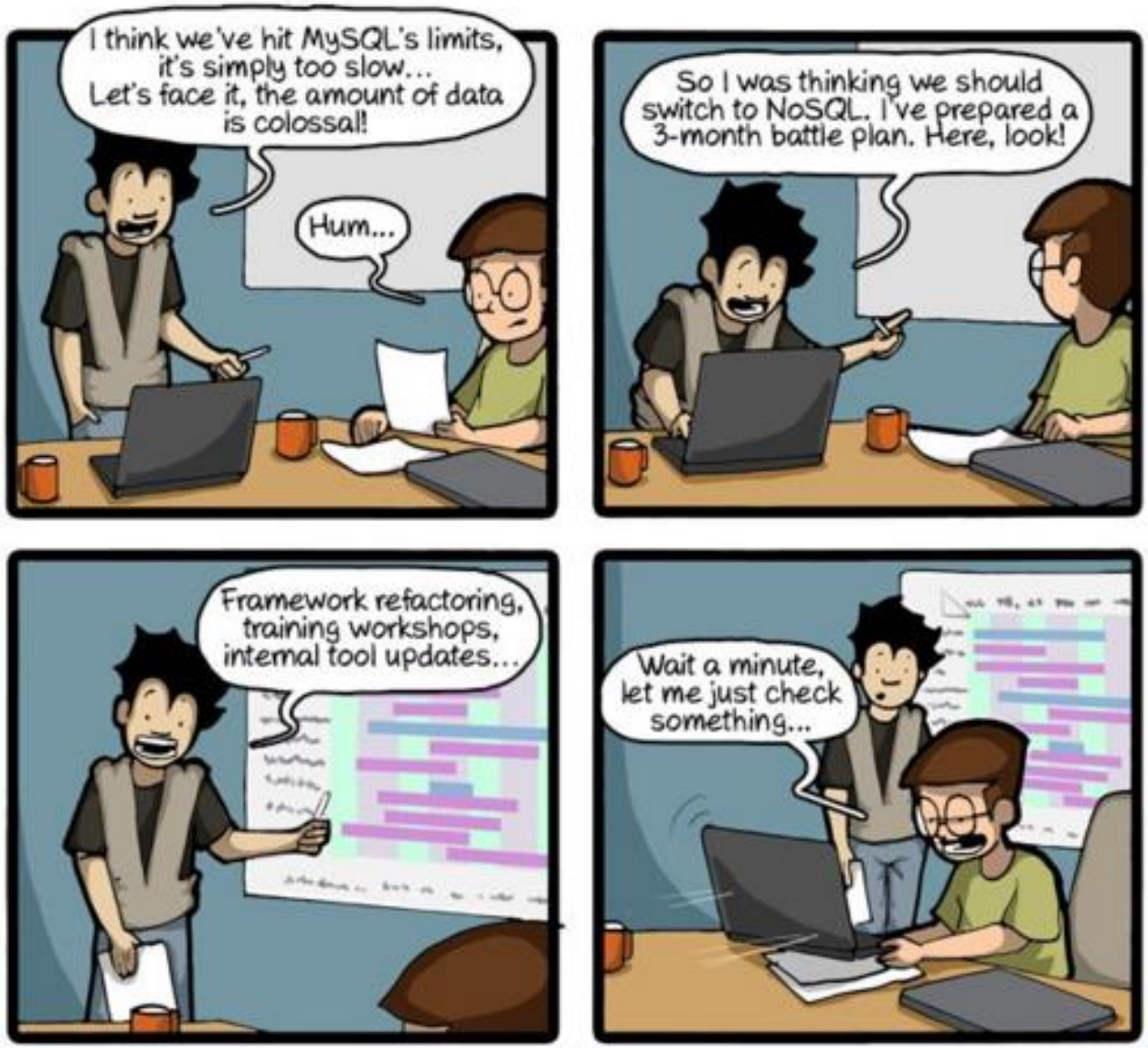
(no longer valid since 2016?)

But:

Software gets slower faster than hardware gets faster

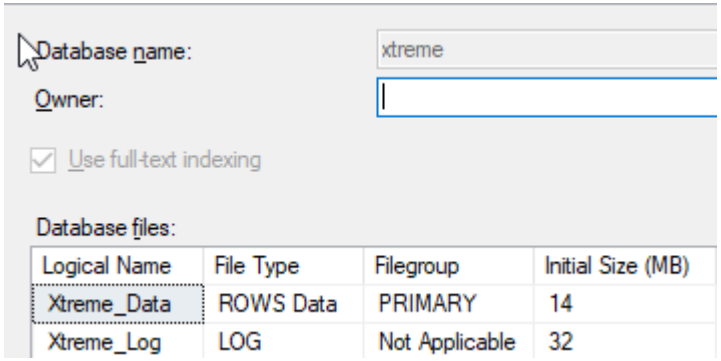
Wirth's law

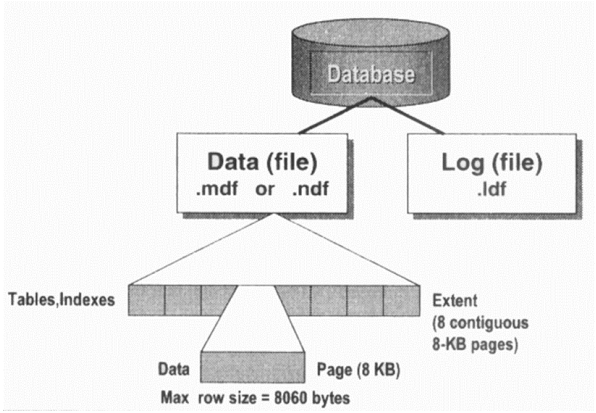
Anyway…


I think we've hit MySQL's limits, it's simply too slow... Let's face it, the amount of data is colossal!
Hum...
So I was thinking we should switch to NoSQL. I've prepared a 3-month battle plan. Here, look!
Framework refactoring, training workshops, internal tool updates...
Wait a minute, let me just check something...

Often indexes offer the solution

Space allocation by SQL Server





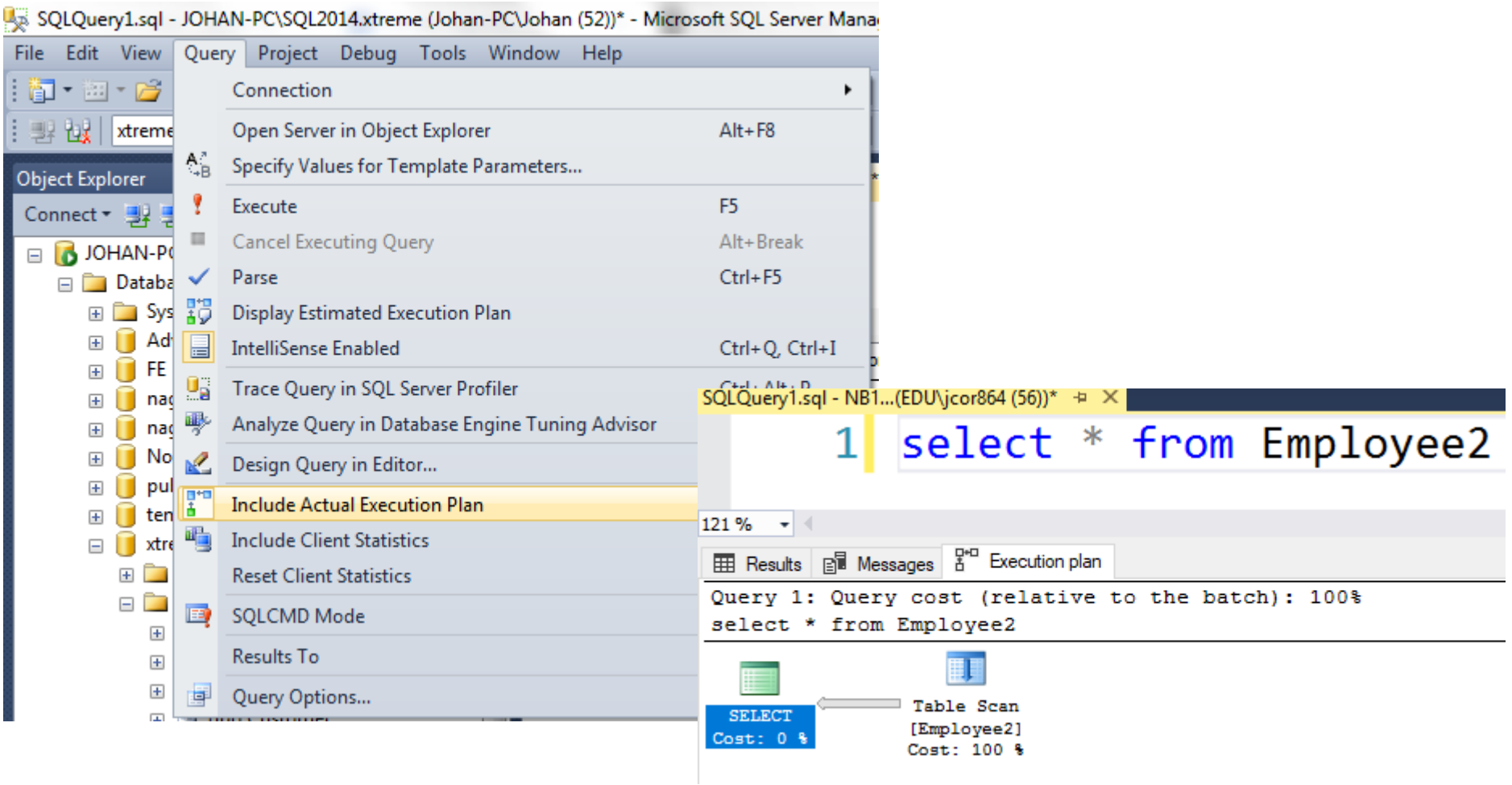
- SQL Server uses random access files
- Space allocation in *extents* and *pages*
- Page = 8 kB block of contiguous space
- Extent = 8 logical consecutive pages.
  - uniform extents: for one db object
  - mixed extents: can be shared by 8 db objects (=tables, indexes)
- New table or index: allocation in mixed extent
- Extension > 8 pages: in uniform extent

Table scan

- heap: unordered collections of data-pages without clustered index (see below) = default storage of a table.
- access via Index Alllocation Map (IAM)
- table scan: if a query fetches all pages of the table → always to avoid!
- Other performance issues with heap:
  - fragmentation: table is scattered over several, non-consecutive pages
  - forward pointers: if a variable length row (e.g. varchar fields) becomes longer upon update, a forward pointer to another page is added.
    → table scan even slower.

Does my query cause a table scan?

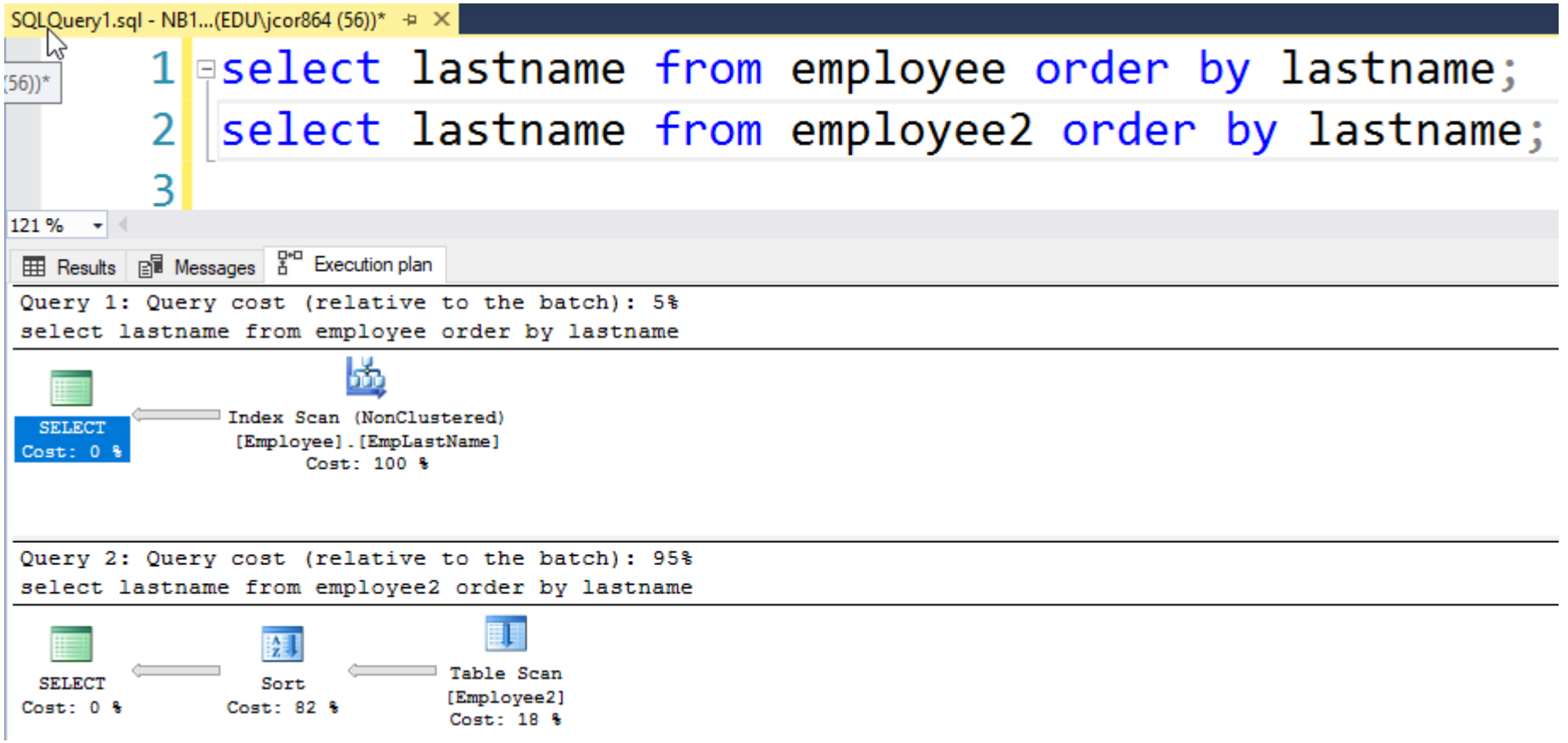
Examine the Execution Plan of the query
(db xtreme, with extra script EmployeeIdx.sql):



Compare 2 queries

(db xtreme, with extra script EmployeeIdx.sql):

- Execute the 2 queries together (select both + Execute!)
- table Employee2 is a copy of Employee, but without indexes
- Query on Employee2 takes 19x longer!



What is the difference? Indexes!

- what?
  - ordered structure imposed on records from a table
  - Fast access through tree structure (B-tree=balanced tree)
- why?
  - Can speed up data retrieval
  - Can force unicity of rows
- Why not ?
  - indexes consume storage (overhead)
  - Indexes can slow down updates, deletes and inserts because indexes has to be updated too.

Indexes: library analogy

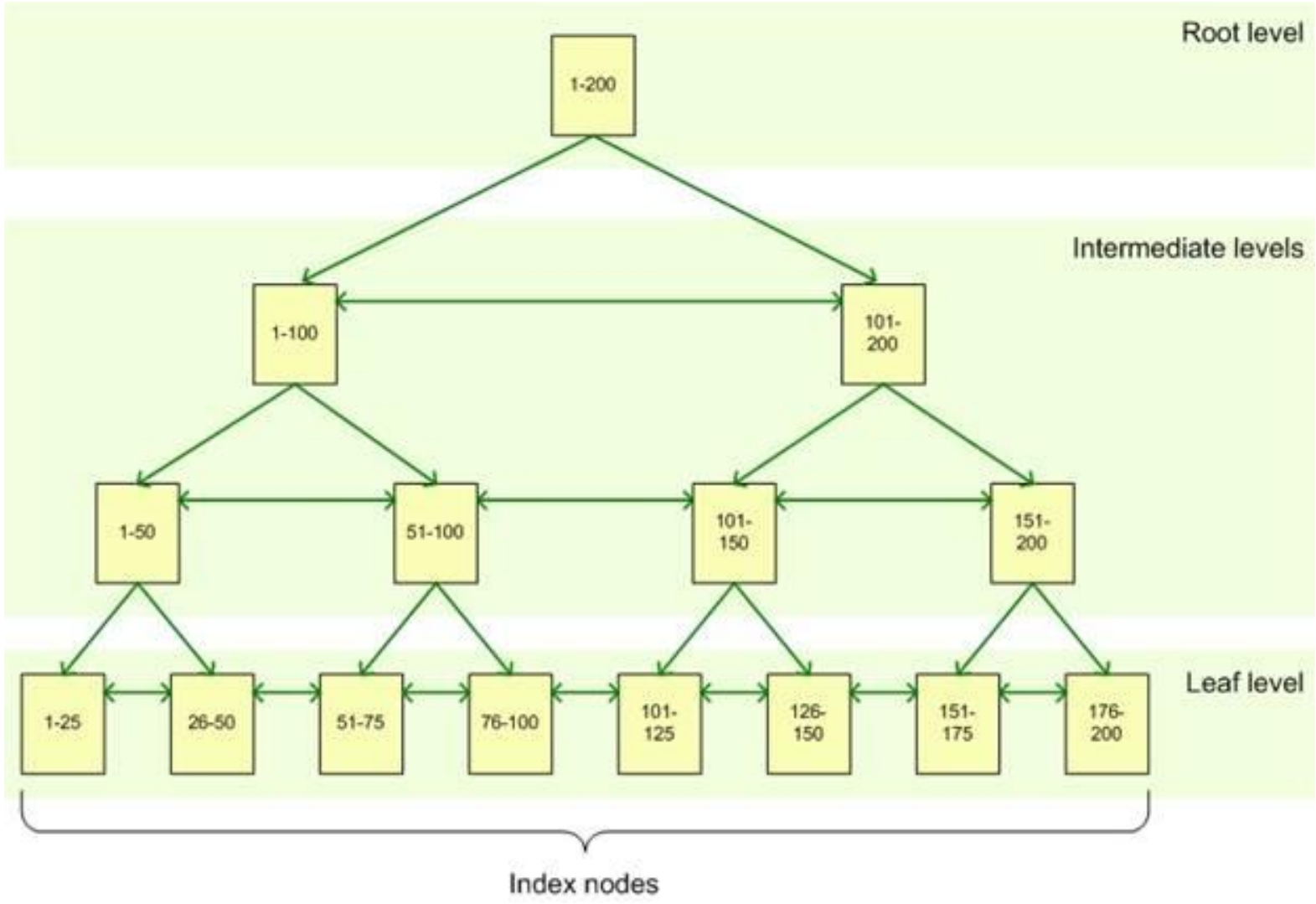
Consider a card catalog in a library. If you wanted to locate a book named Effective SQL, you would go to the catalog and locate the drawer that contains cards for books starting with the letter E (maybe it will actually be labeled D–G). You would then open the drawer and flip through the index cards until you find the card you are looking for. The card says the book is located at 601.389, so you must then locate the section somewhere within the library that houses the 600 class. Arriving there, you have to find the bookshelves holding 600–610. After you have located the correct bookshelves, you have to scan the sections until you get to 601, and then scan the shelves until you find the 601.3XX books before pinpointing the book with 601.389.

In an electronic database system, it is no different. The database engine needs to first access its index on data, locate the index page(s) that contains the letter E, then look within the page to get the pointer back to the data page that contains the sought data. It will jump to the address of the data page and read the data within that page(s). Ergo, an index in a database is just like the catalog in a library. Data pages are just like bookshelves, and the rows are like the books themselves. The drawers in the catalog and the bookshelves represent the B-tree structure for both index and data pages.

SQL Optimizer

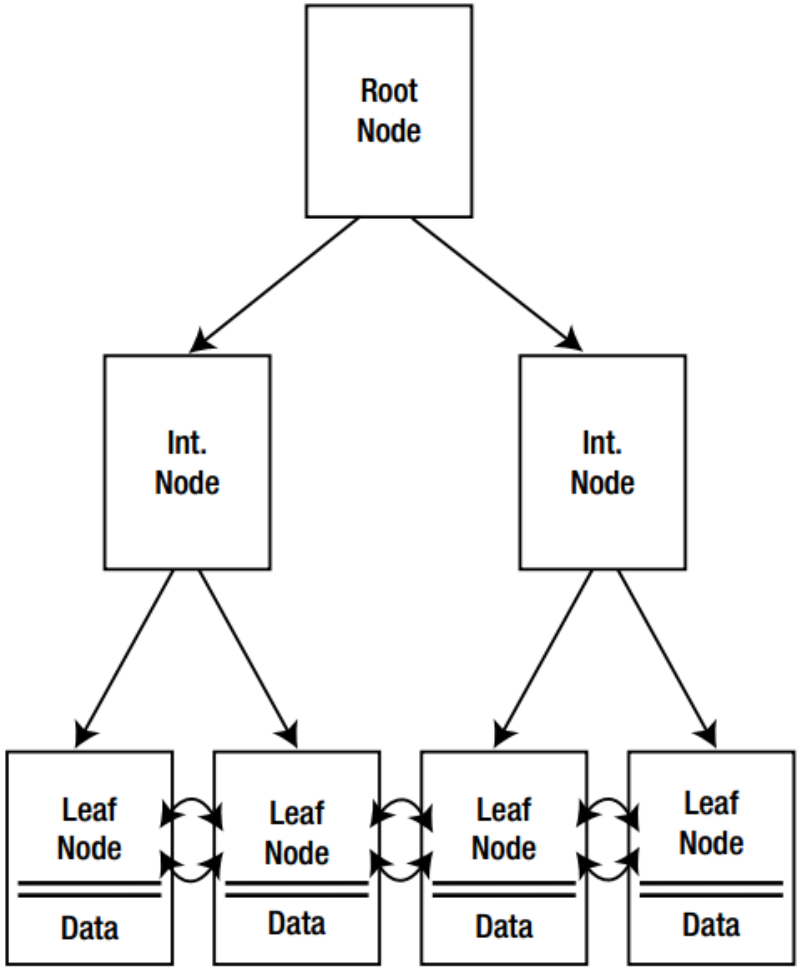
- SQL Optimizer: module in each DBBMS
- Analyses and rephrases each SQL command sent to the DB
- Decides optimum strategy for e.g. index use based on statistics about table size, table use and data distribution.
- In SQL searching is used for fields in *where*, *group by*, *having* and *order by* clauses and for fields that are *join*ed.

Indexes as B-trees



Clustered index

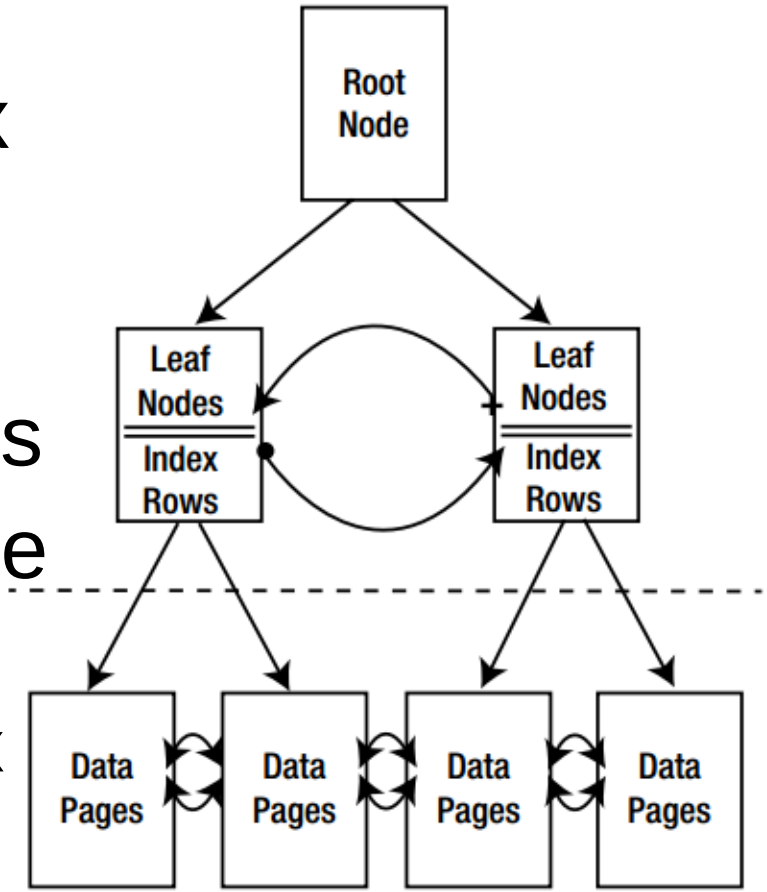
- The physical order of the rows in a table corresponds to the order in the clustered index.
- As a consequence, each table can have only one clustered index.
- The clustered index imposes unique values and the primary keys constraint
- Advantages as opposed to table scan:
  - double linked list ensures order when reading sequential records
  - no forward pointers necessary



Int. Node = intermediate(tussenliggende) node

Non clustered index

- default index
- slower than clustered index
- > 1 per table allowed
- Forward and backward pointers between leaf nodes
- each *leaf* contains key value and *row locator*
  - to position in clustered index if it exists
  - otherwise to heap



Non clustered index

- if query needs more fields than present in index, these fields have to be fetched from data pages.
- when reading via non-clustered index:

either:

  – RID lookup = bookmark lookups to the heap using RID's (= row identifiers)

or:

  – key lookup = bookmark lookups to a clustered index, if present

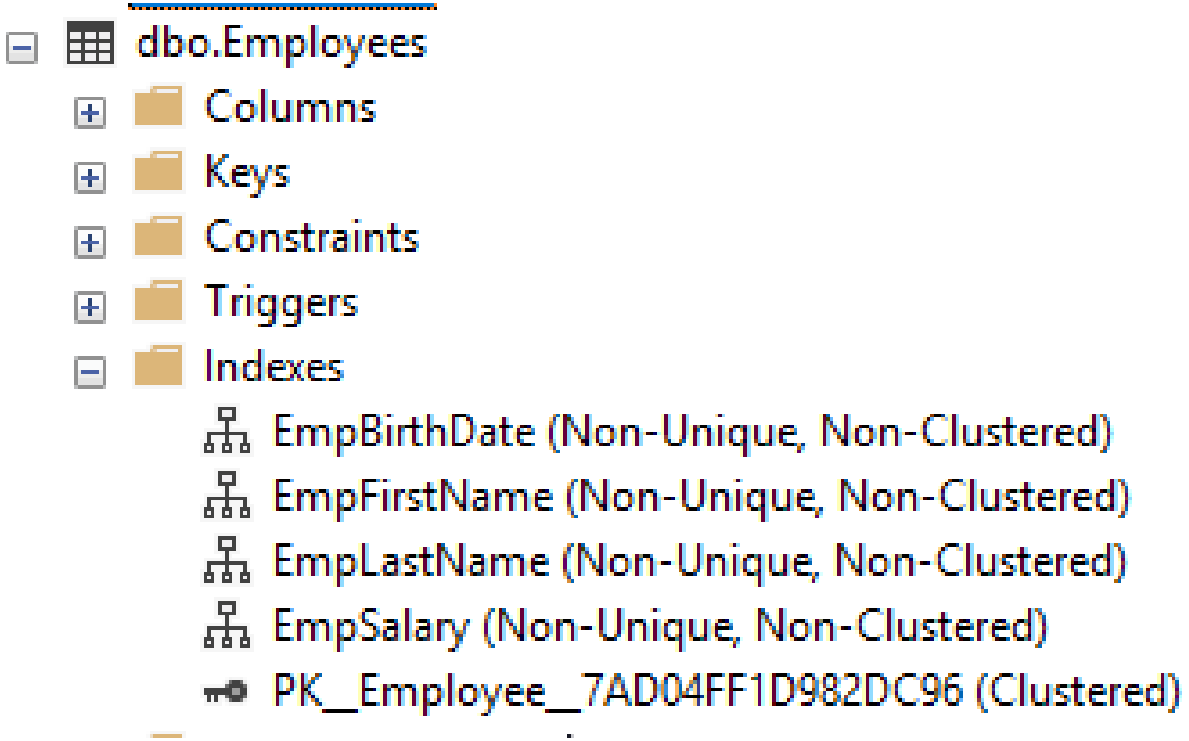
Covering index

- if a non clustered index not completely *covers* a query, SQL Server performs a lookup for each row to fetch the data
- covering index=non-clustered index containing all columns necessary for a certain query
- with SQL Server you can add extra columns to the index (although those columns are not indexed!)

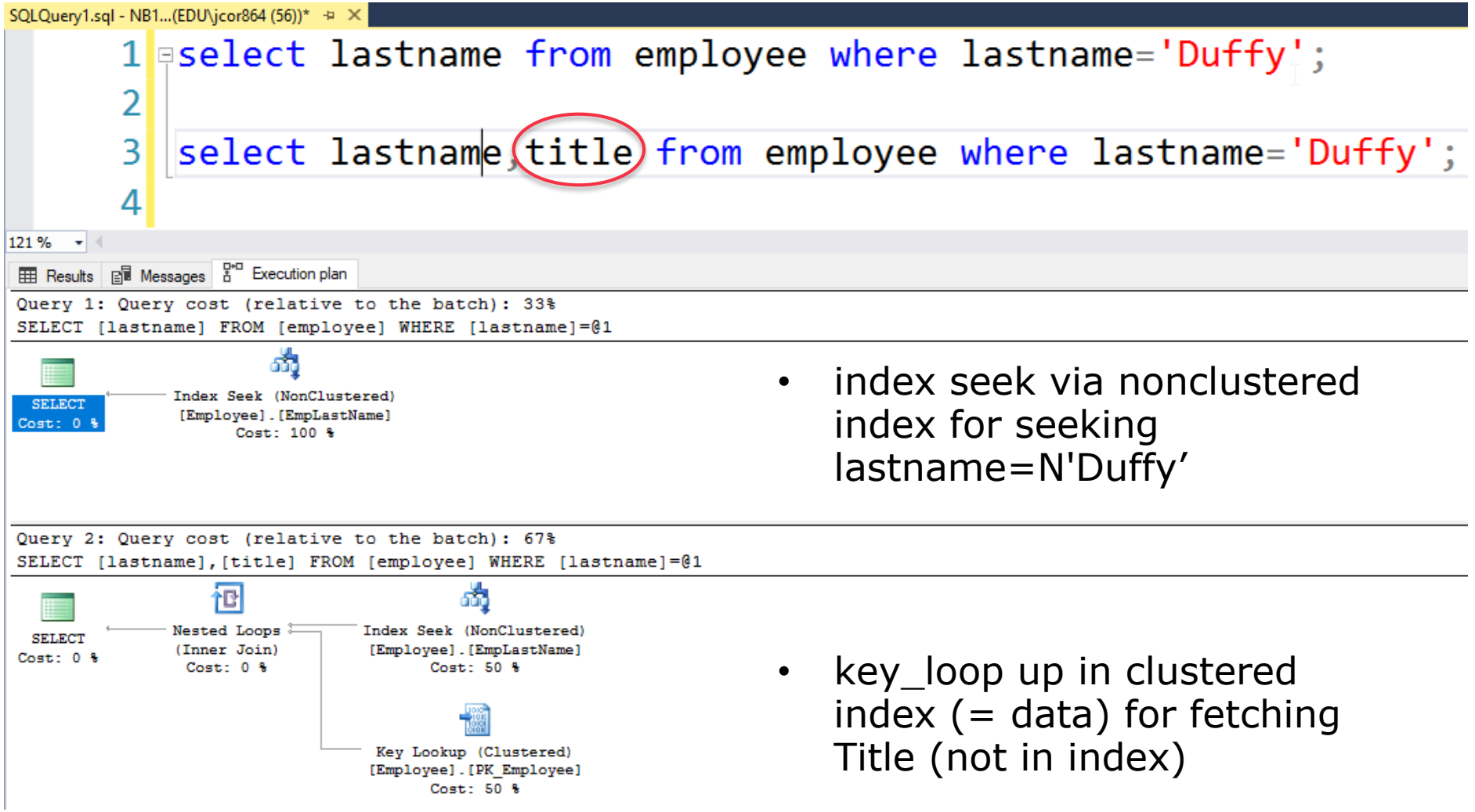
Covering index: example (db xtreme, with extra script EmployeeIdx.sql):

Current indexes on table Employee:

each index indexes a single field.



Covering index: example
(db xtreme, with extra script EmployeeIdx.sql):

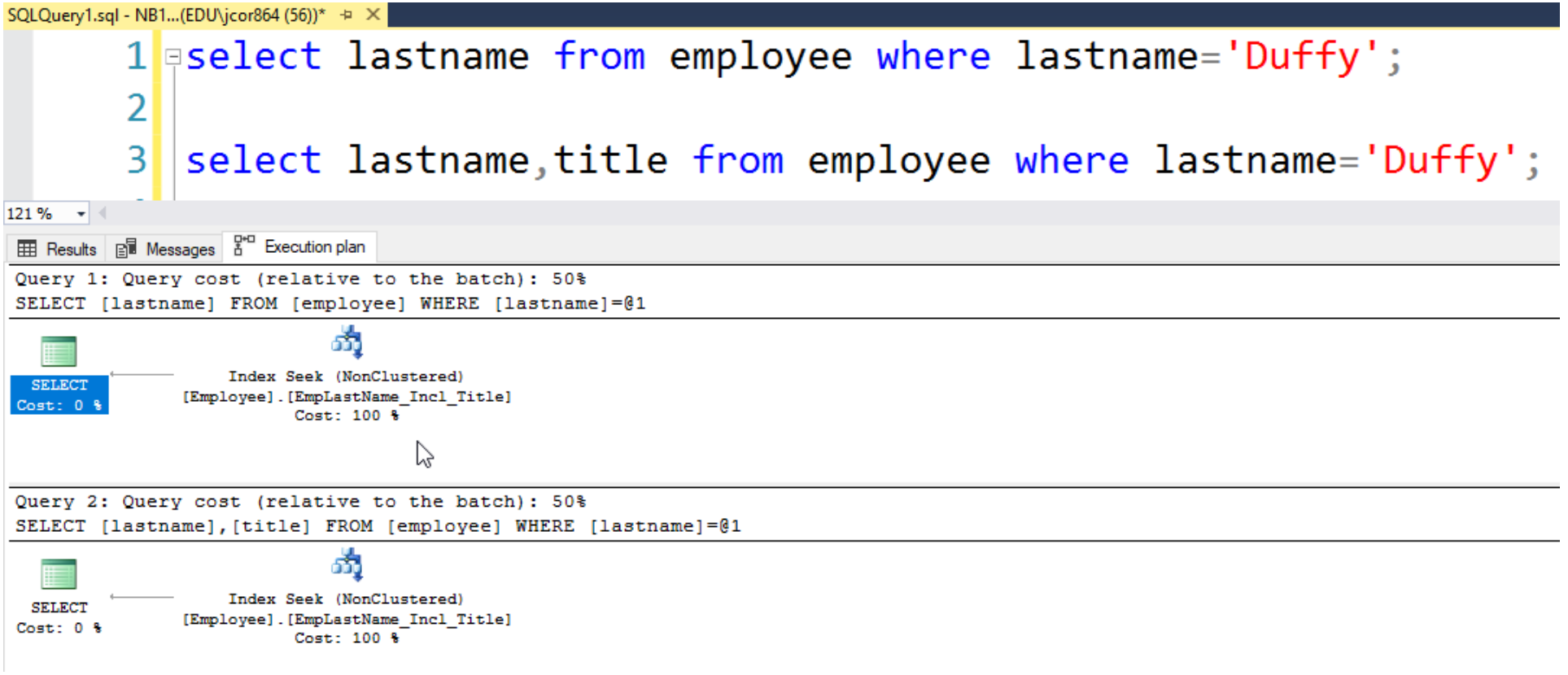


- index seek via nonclustered index for seeking lastname=N'Duffy’
- key_loop up in clustered index (= data) for fetching Title (not in index)

Covering index: example (cont'd)

Solution: covering index via INCLUDE

```
create nonclustered index EmpLastName_Incl_Title
ON employee(lastname) INCLUDE (title);
```



1 index with several columns vs. several indexes with 1 column

```
create nonclustered index EmpLastName ON employee(lastname);
 +
create nonclustered index EmpFirstname ON
employee(firstname);
```

OR

?

```
create nonclustered index EmpLastNameFirstname ON
employee(lastname,firstname);
```

1 index with several columns vs. several indexes with 1 column

Rule in SQL Server:

When querying (ex. in where-clause) only 2nd and or 3th, …field of index, it is not used. This directly follows from the B-tree table structure of the composed index

So:

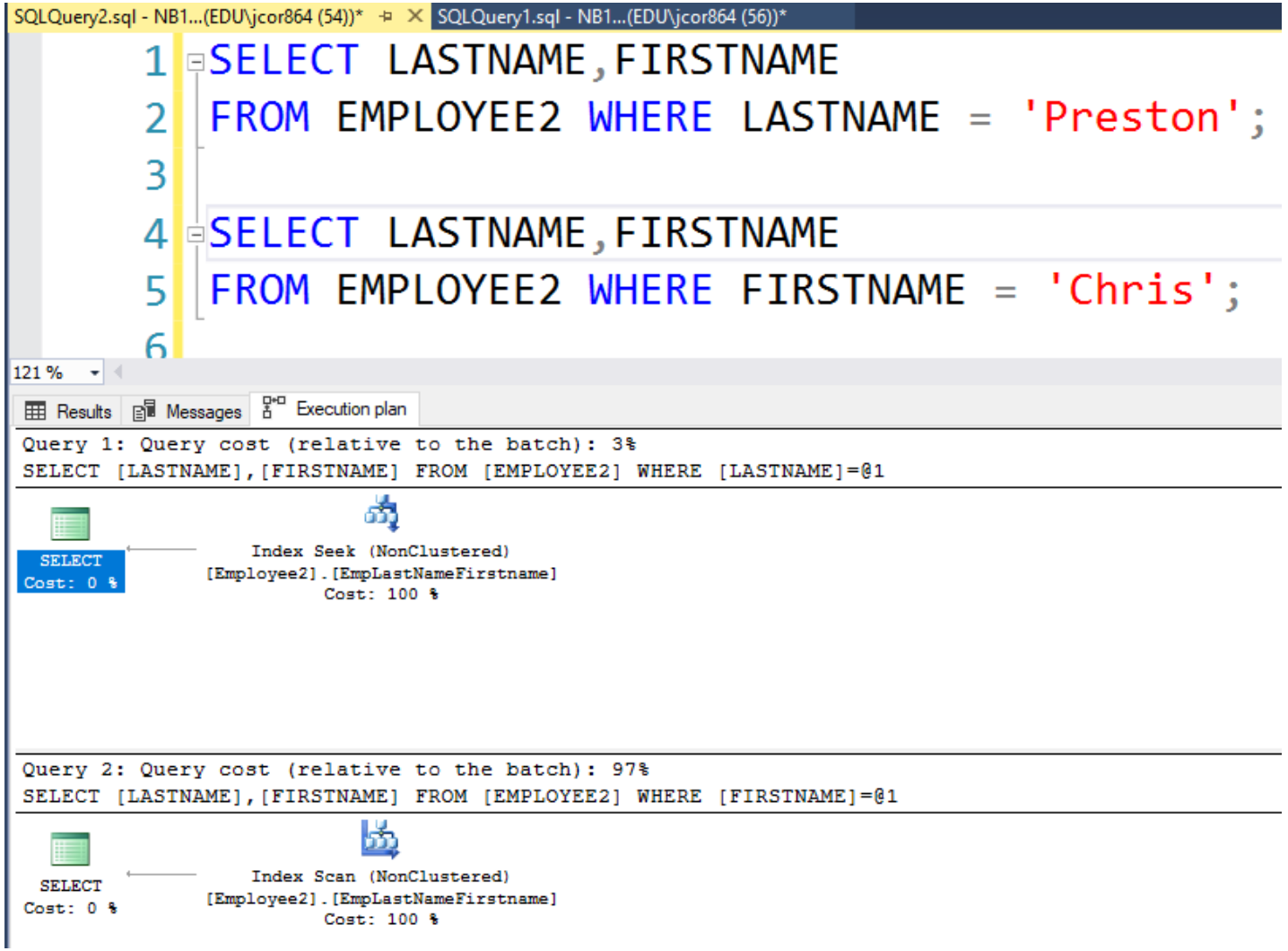
```
SELECT LASTNAME,FIRSTNAME
FROM EMPLOYEE2
WHERE FIRSTNAME = 'Chris';
```

does not use the double index

Conclusion: make your indexes according to the most commonly used queries.

1 index met several columns vs. several indexes with 1 column

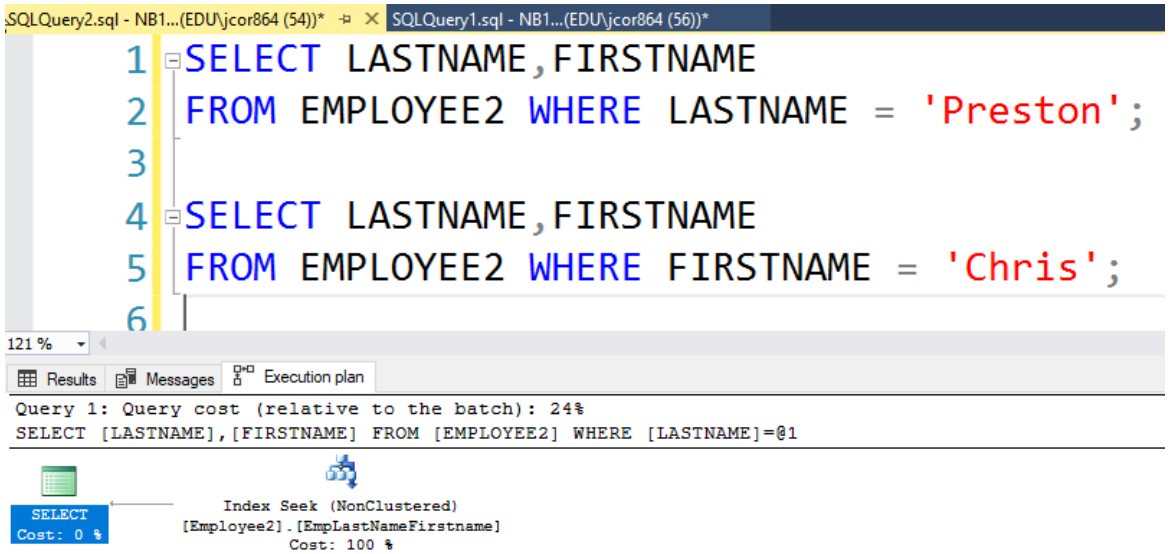
Test: only combined index on Lastname, Firstname

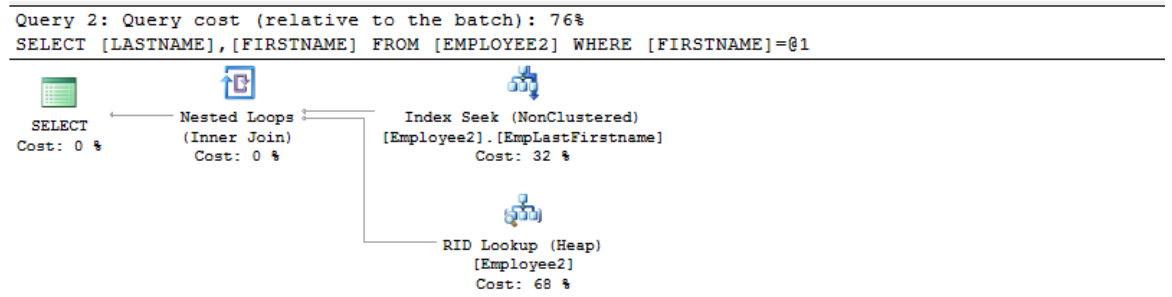


1 index met several columns vs. several indexes with 1 column

test: extra index on Firstname:

```
create nonclustered index EmpLastFirstname ON employee2(firstname);
```





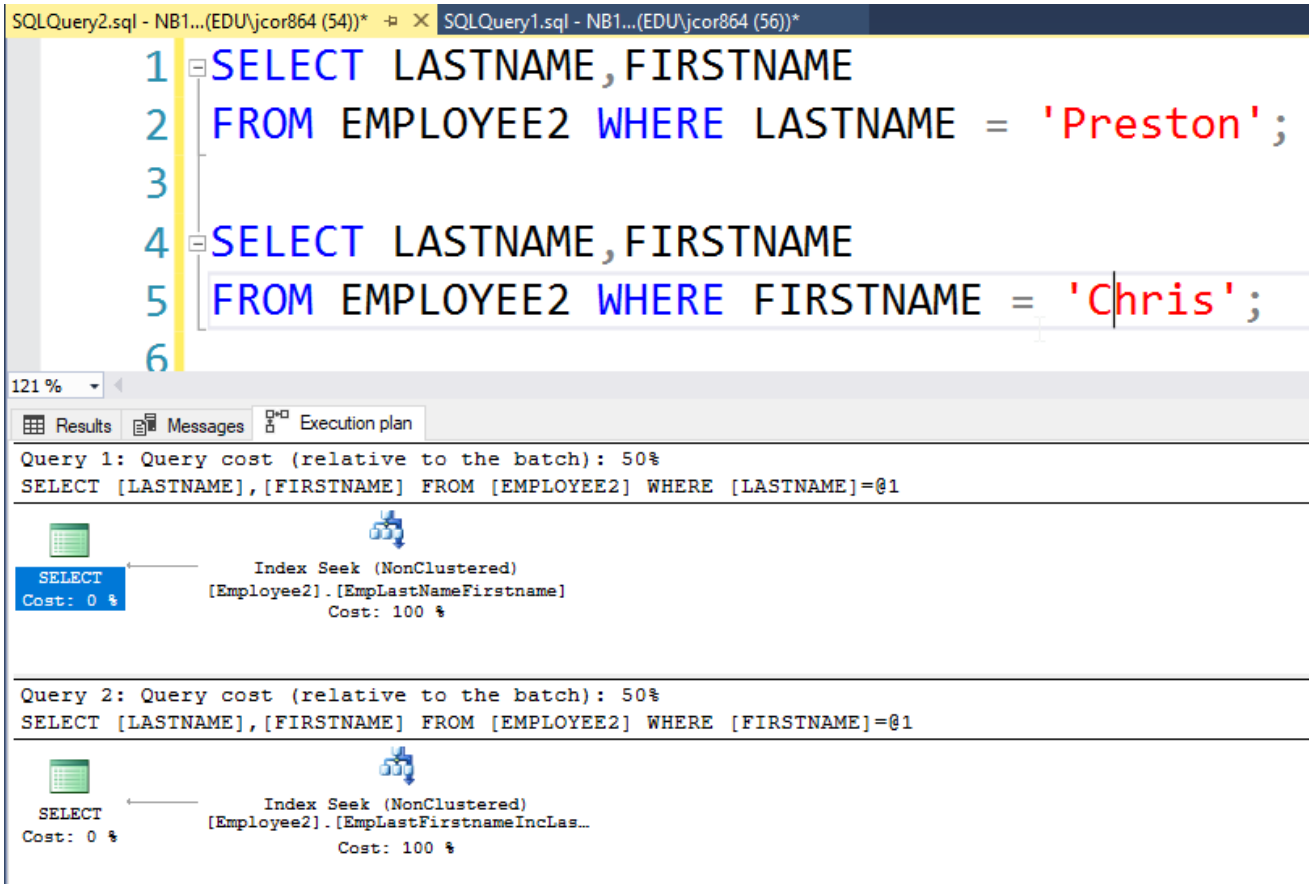
not a spectacular improvement because of fetching lastname through lookup

→ covering index with include 'lastname'

1 index met several columns vs. several indexes with 1 column

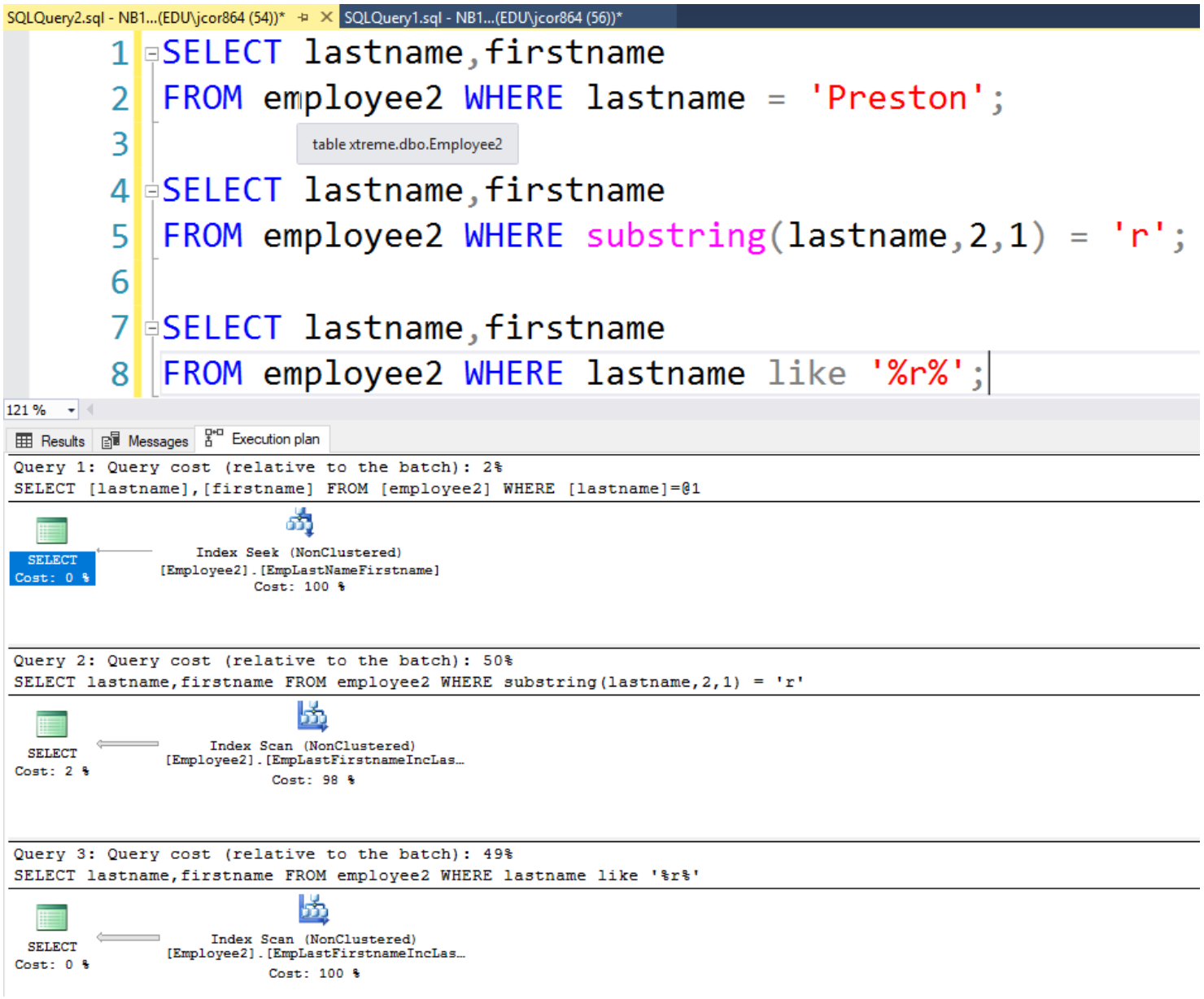
test: with extra index on Firstname and covering of Lastname

```
create nonclustered index EmpLastFirstnameIncLastname
ON employee2(firstname) INCLUDE (lastname);
```



now query execution times are equal.

Use of indexes with functions and wildcards



Creation of indexes: syntax

```
CREATE [UNIQUE] [| NONCLUSTERED]
  INDEX index_name ON table (kolom [,...n])
```

create index

```
create index ssnr_index on student(ssnr)
```

create index

- **unique** all values in the indexed column should be unique
- remark:
  - when defining an index the table can be empty or filled.
  - columns in a **unique** index should have the **not null** constraint

removing indexes

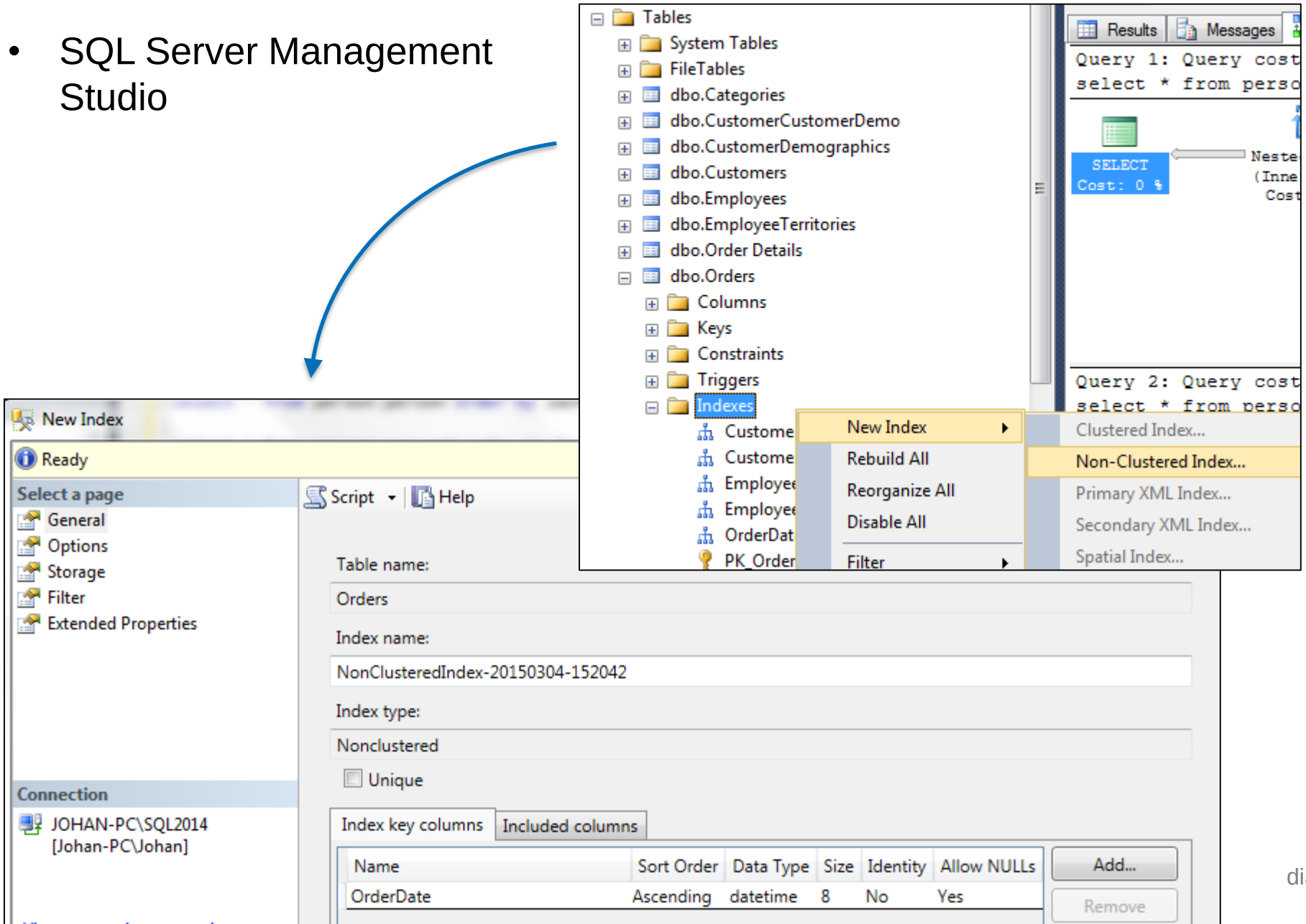
```
DROP INDEX table_name.index [,...n]
```

deleting index

```
drop index student.SSNR_Index
```

Working with indexes

- SQL Server Management Studio



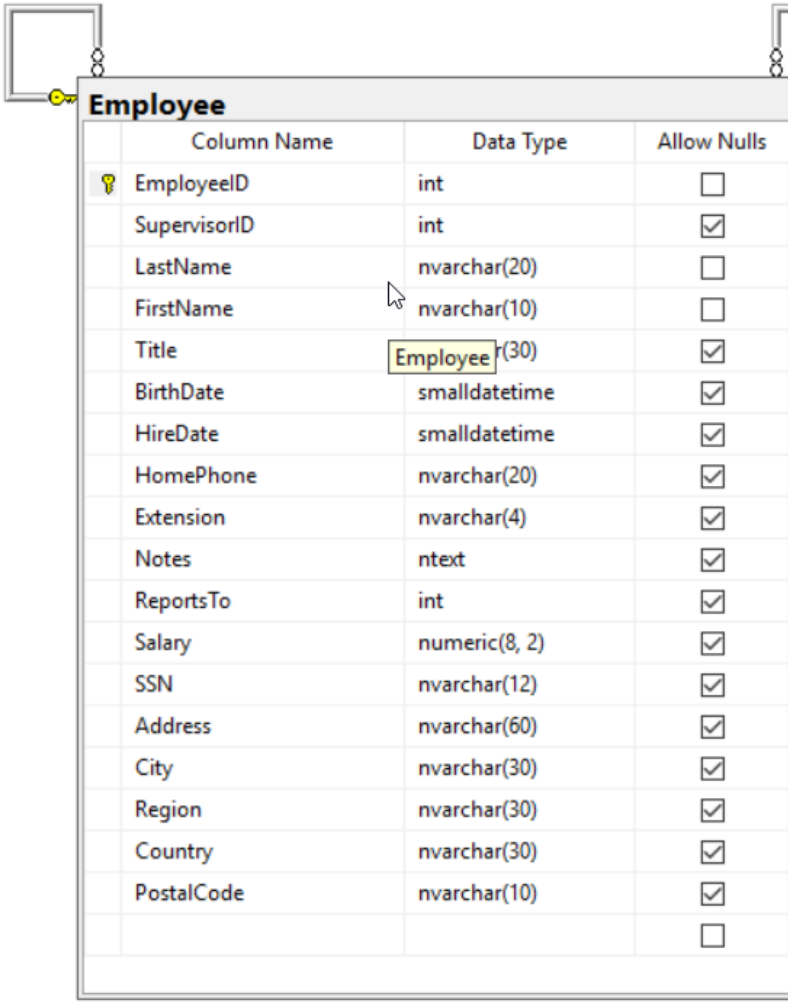
When to use an index

- **which columns should be indexed?**
  - primary and unique columns are index automatically
  - foreign keys often used in joins
  - columns often used in search conditions (WHERE, HAVING, GROUP BY) or in joins
  - columns often used in the ORDER BY clause
- **which columns should not be indexed?**
  - columns that are rarely used in queries
  - columns with a small number of possible values (e.g. gender)
  - columns in small tables
  - columns of type bit, text of image

Tips & tricks

DB xtreme:

```
CREATE INDEX EmpFirstName ON
Employee (FirstName ASC);
CREATE INDEX EmpLastName ON
Employee (LastName ASC);
CREATE INDEX EmpDOB ON
Employee (BirthDate ASC);
CREATE INDEX EmpSalary ON
Employee (Salary ASC);
```

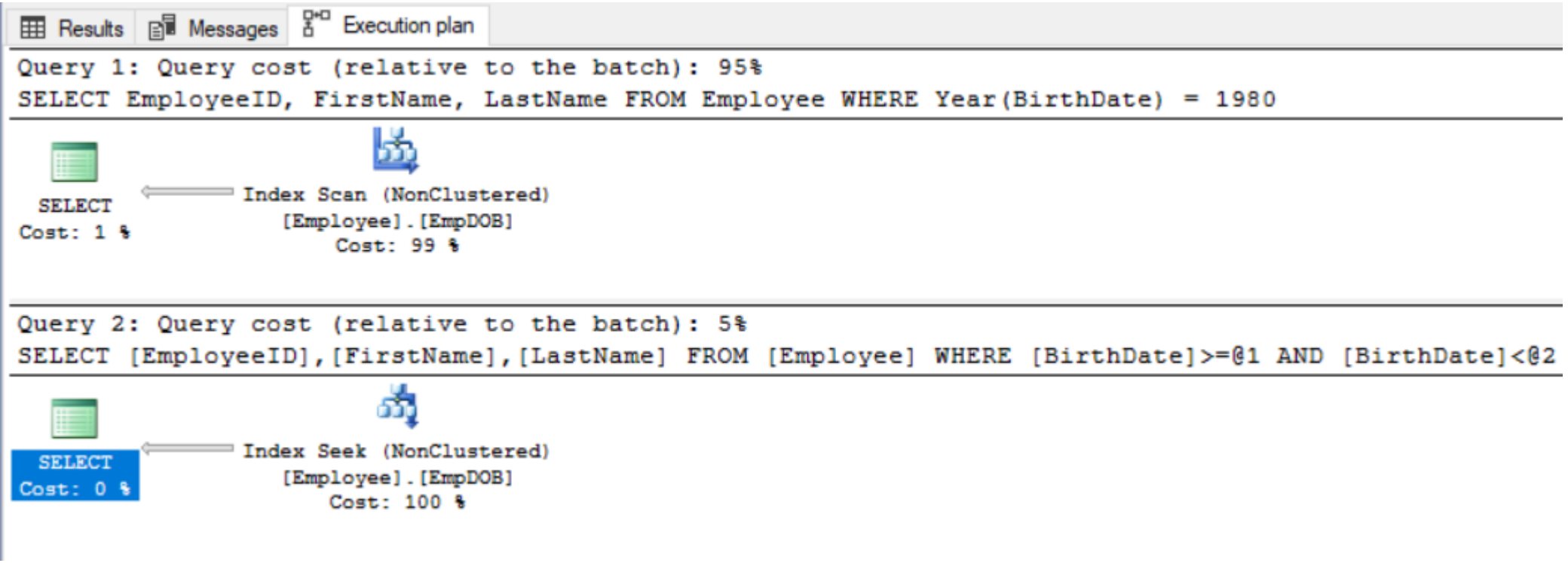


The following slides provides some general rules of thumb that are applicable in most cases on most databases. They are not carved in stone.
The employee table used in the examples has about 20.000 records.

Tips & tricks: (1) avoid the use of functions

```sql
-- BAD
SELECT EmployeeID, FirstName, LastName
FROM Employee
WHERE Year(BirthDate) = 1980;

-- GOOD
SELECT EmployeeID, FirstName, LastName
FROM Employee
WHERE BirthDate >= '1980-01-01'
AND BirthDate <  '1981-01-01';
```

Tips & tricks: (1) avoid the use of functions



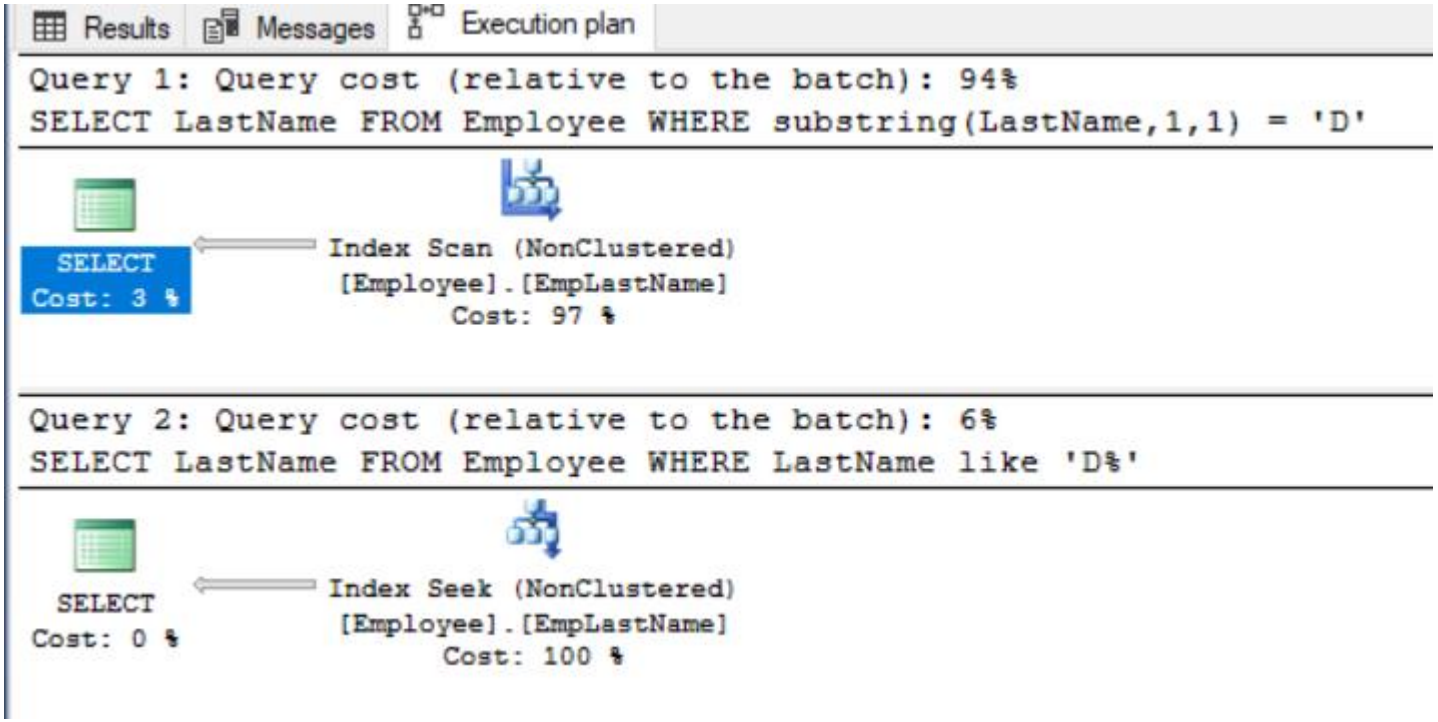
- Index Scan: index is used but it is scanned from the start till the searched records are found.

- Index Seek: tree structure of index is used, resulting in very fast data retrieval.

Tips & tricks: (2) avoid the use of functions

```sql
-- BAD
SELECT LastName
FROM Employee
WHERE substring(LastName,1,1) = 'D';

-- GOOD
SELECT LastName
FROM Employee
WHERE LastName like 'D%';
```

Tips & tricks: (2) avoid the use of functions



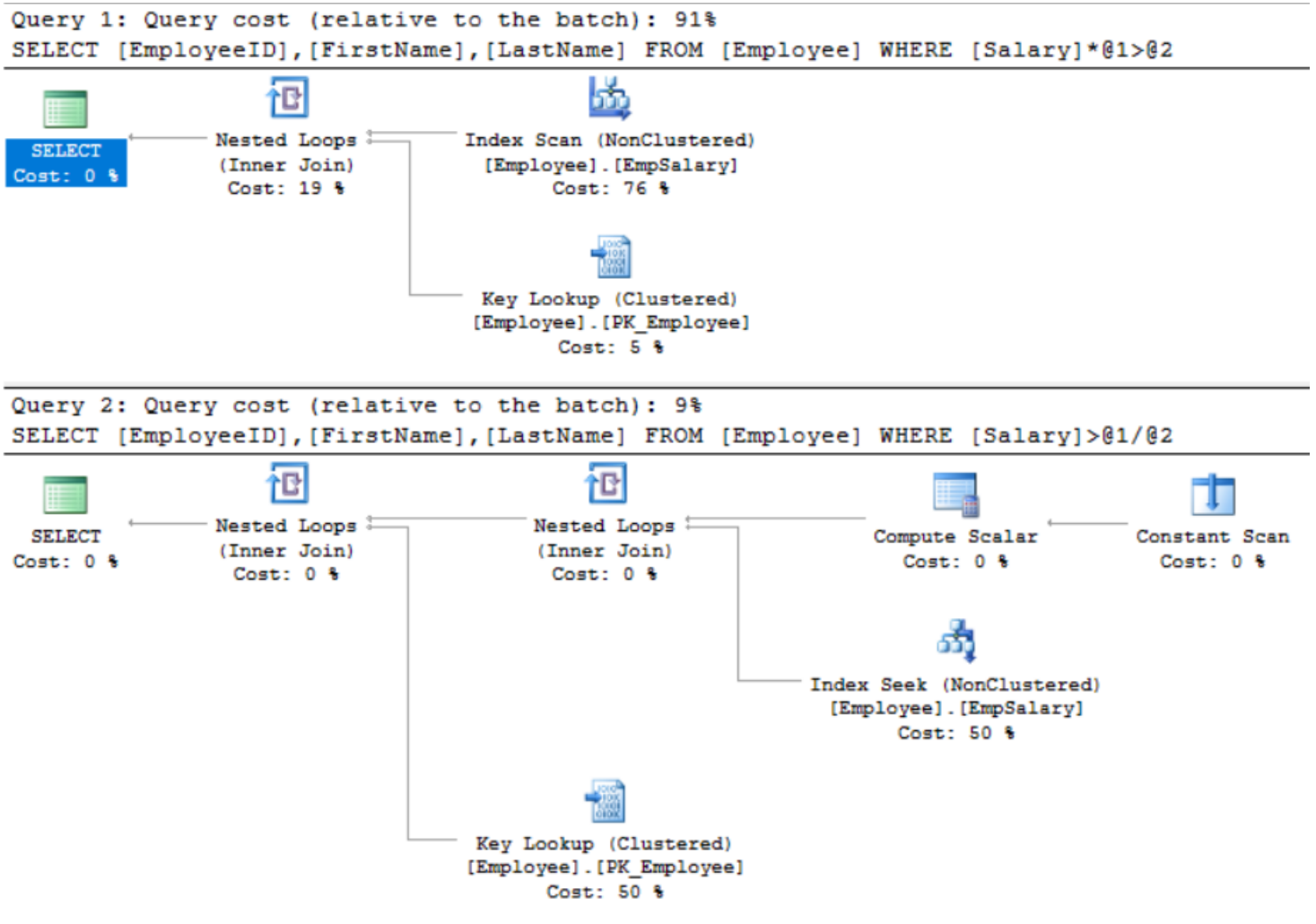
- Index Scan: index is used but it is scanned from the start till the searched records are found.

- Index Seek: tree structure of index is used, resulting in very fast data retrieval.

Tips & tricks
(3) avoid calculations, isolate columns

```sql
-- BAD
SELECT EmployeeID, FirstName, LastName
FROM Employee
WHERE Salary*1.10 > 100000;

-- GOOD
SELECT EmployeeID, FirstName, LastName
FROM Employee
WHERE Salary > 100000/1.10;
```

Tips & tricks:
(3) avoid calculations, isolate columns



Key lookup:

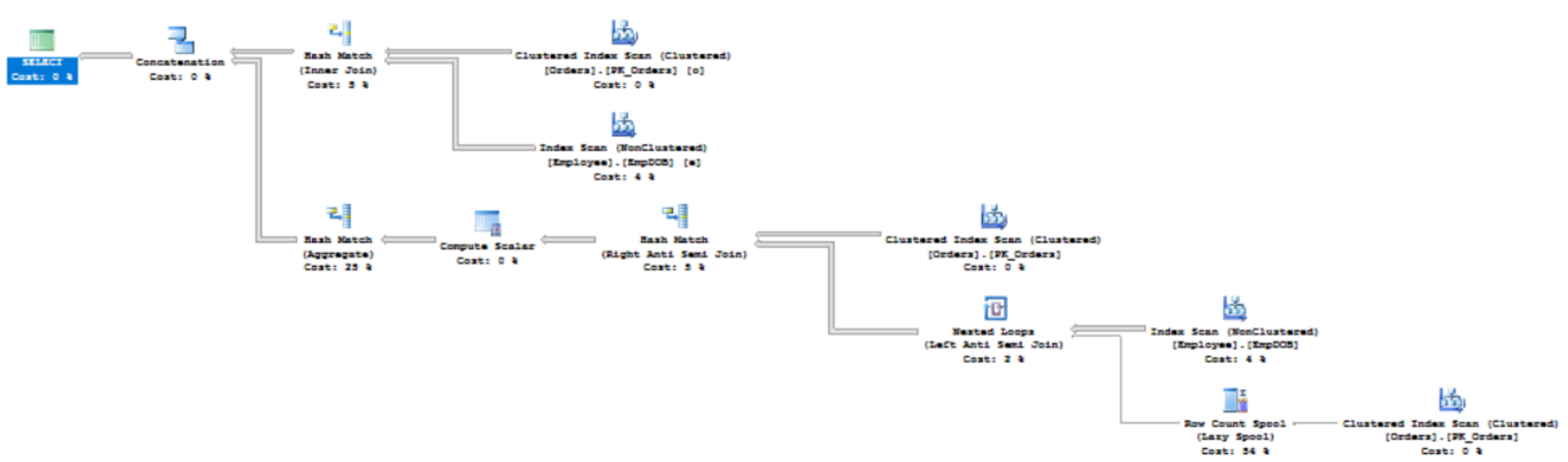
The non-clustered index EmpSalary, holds in each leaf a reference to the location of the total record in the clustered index. Following this reference is called “key lookup”.

Tips & tricks
(4) prefer OUTER JOIN above UNION

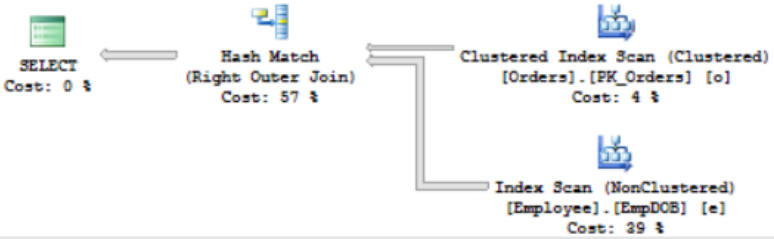
```
-- BAD
SELECT lastname,firstname,orderid
from Employee e join Orders o on e.EmployeeID =
o.employeeid
union
select lastname,firstname,null
from Employee where EmployeeID not in (select EmployeeID
from Orders)

-- GOOD
SELECT lastname,firstname,orderid
from Employee e left join Orders o on e.EmployeeID =
o.employeeid;
```

Tips & tricks:
(4) prefer OUTER JOIN above UNION

```
Query 1: Query cost (relative to the batch): 91%
SELECT lastname,firstname,orderid from Employee e join Orders o on e.EmployeeID = o.employeeid union select lastname,firstname,null fr
```



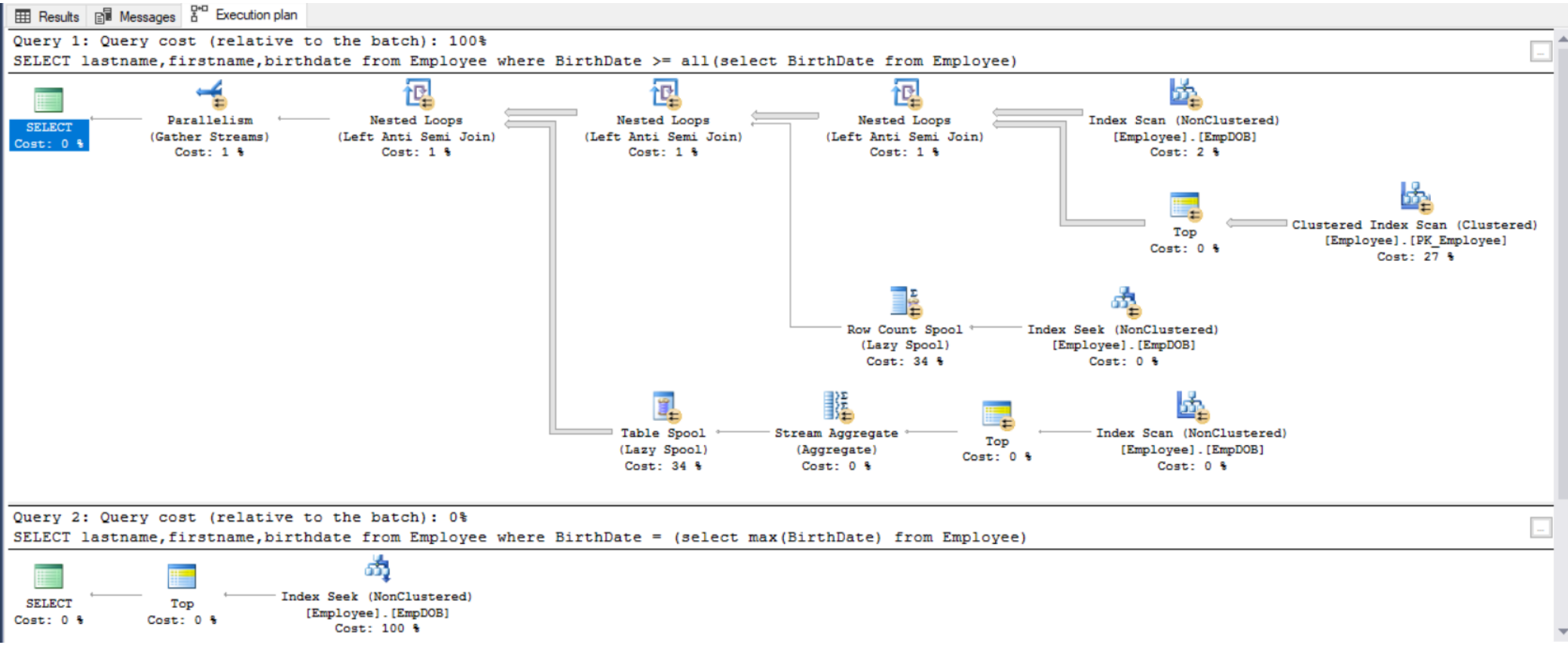

```
Query 2: Query cost (relative to the batch): 9%
SELECT lastname,firstname,orderid from Employee e left join Orders o on e.EmployeeID = o.employeeid
```



Tips & tricks
(5) avoid ANY and ALL

```
-- BAD
SELECT lastname,firstname,birthdate
from Employee where BirthDate >=
all(select BirthDate from Employee)

-- GOOD
SELECT lastname,firstname,birthdate
from Employee where BirthDate =
(select max(BirthDate) from Employee)
```

Tips & tricks:
(5) avoid ANY and ALL



Quiz 1/5

Is the following index a good fit for the query?

```
CREATE INDEX tbl_idx ON tbl (date_column);

SELECT * FROM tbl
WHERE YEAR(date_column) = 2017;
```

A. Good fit: No need to change anything
B. Bad fit: Changing the index or query could improve performance

Quiz 2/5

Is the following index a good fit for the query?

```
CREATE INDEX tbl_idx ON tbl (a, date_column);

SELECT TOP 1 * FROM tbl
  WHERE a = 12
  ORDER BY date_column DESC;
```

A. Good fit: No need to change anything
B. Bad fit: Changing the index or query could improve performance

Quiz 3/5

Is the following index a good fit for both queries?

```
CREATE INDEX tbl_idx ON tbl (a, b);

SELECT * FROM tbl
 WHERE a = 123 AND b = 1;

SELECT * FROM tbl WHERE b = 123;
```

A. Good fit: No need to change anything
B. Bad fit: Changing the index or query could improve performance

Quiz 4/5

Is the following index a good fit for the query?

```
CREATE INDEX tbl_idx ON tbl (text);


SELECT *
FROM tbl
WHERE text LIKE 'TJ%';
```

A. Good fit: No need to change anything
B. Bad fit: Changing the index or query could improve performance

Quiz 5/5

This question is different. First consider the following index and query:

```
CREATE INDEX tbl_idx ON tbl (a, date_column);

SELECT date_column, count(*)
  FROM tbl
 WHERE a = 123
 GROUP BY date_column;
```

Let's say this query returns at least a few rows. To implement a new functional requirement, another condition (b = 1) is added to the where clause:

```
SELECT date_column, count(*) FROM tbl
 WHERE a = 123 AND b = 1
 GROUP BY date_column;
```

How will the change affect performance:

A. Same: Query performance stays about the same
B. Not enough information: Definite answer cannot be given
C. Slower: Query takes more time
D. Faster: Query take less time

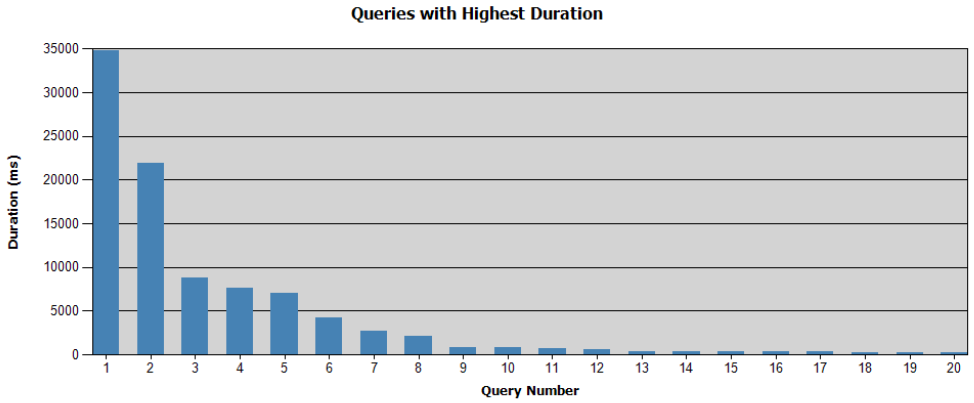
Looking for "expensive" queries

Install the performance dashboard according to the guidelines in

http://blog.sqlauthority.com/2014/09/22/sql-server-ssms-performance-dashboard-installation-and-configuration/

Start via Database/Reports/Custom reports…

example of a rapport: Expensive queries by duration:



Query Number	Representative Query	Total Executes	Cached Query Count	Unique Plan Count	Highest Plan Generation	Earliest Plan Cached	Cumulative CPU (ms)	Cumulative Duration (ms)				Cumulative Physical Reads	Cumulative Logical Reads
							Total	Total	Max	Avg	Min	Total	Total
1	select * from person.person order by person.person.LastName,firstnam	6	3	1	1	3/4/2015 2:22:41 PM	4,378.468	34,813.075	24,848.507	5,802.179	1,874.773	3,926	415,90
2	SELECT ISNULL((case dmi.mirroring_redo_queue_type when N'UNLIMITED' then 0 else dmi.mirroring_redo_queue end),0) AS [MirroringRedoQueueMaxSize], ISNULL(dmi.mirroring_connection_timeout,0) AS [MirroringTimeout], ISNULL(dmi.mirroring_partner_name,'') AS [MirroringPartner], ISNULL(dmi.mirroring_partner_instance,'') AS [MirroringPartnerInstance], ISNULL(dmi.mirroring_role,0) AS [MirroringRole], ISNULL(dmi.mirroring_safety_level + 1, 0) AS [MirroringSafetyLevel], ISNULL(dmi.mirroring_state + 1, 0) AS [MirroringStatus], ISNULL(dmi.mirroring_witness_name,'') AS [MirroringWitness],	419	1	1	1	3/4/2015 11:51:51 AM	6,302.242	21,859.012	346.418	52.169	0.489	6,199	56,77